Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SCG060-04 Room:302 Time:May 25 09:15-09:30

Metamorphic fluid composition determined by trace element and isotopic composition analysis of metamorphic rocks

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Regional metamorphic belts provide unique information that is directly relevant to the fluid behavior at plate convergent margin. Petrological and geochemical analyses of the regional metamorphic rocks would resolve not only the composition and amount of geofluids in subduction zones, which can be assessed by those of arc volcanic rocks, but also the transport mechanism of geofluids through quantification of fluid-related textures. However, previous studies on composition, amount, transport-scale of geofluids during metamorphism are inconsistent with each other (e.g. Ferry, 1992; Bebout, 2007). Although the bulk composition of metamorphic rocks represents integration of processes from subduction to exhumation, previous studies did not decode the processes, including sea floor alteration, dehydration and rehydration during subduction, which likely resulted in misinterpretations. Rehydration reaction, in particular, overprints the other two processes (e.g. Okamoto&Toriumi, 2005). In order to understand the fluid processes relevant to metamorphism, it is, therefore, required to identify and separate the processes and the associated material transport.

In this study, we aim to constrain fluid behavior in metamorphism, especially composition, amount, timing of fluid during rehydration reaction in the late stage of metamorphism by comparing geochemical data (bulk trace element and isotopic compositions, bulk water content) with petrogenetic physico-chemical conditions of P-T path, mineralogy and extent of rehydration.

The Sanbagawa metamorphic belt, a subduction-related high P/T-type regional metamorphic belt, was selected for this study, for which extensive petrogenetic information is available. For metabasaltic samples in each metamorphic grade, major and trace elements and Pb isotope analysis were conducted. Mineral composition analysis by EPMA and determination of P-T paths by thermodynamic analysis have been also performed for a part of the samples.

Consequently, we obtained the following results:
(1)Trace element compositions of metabasites are approximately between the altered oceanic crust and oceanic sediments.
(2)Analyzed trace elements can be divided into the following 3 groups:
1. Elements whose concentration differs according to metamorphic grade.
2. Elements whose concentration is proportional to bulk water (LOI).
3. Elements which do not have trends above.
(3)Pb isotopic compositions corrected by rehydration age are not aligned on the mixing line between AOC and sediments, but have higher $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratio.
(4)Pb isotopic compositions of metabasites form a trend that corresponds to the IC2 components of global basalt composition proposed by Iwamori et al. (2010), which reflects hydration-dehydration process.

From samples corrected from a single basic block, a linear relationship between elements in (2)-2 and extent of rehydration was found, and fluid composition during rehydration was determined. The concentrations of each element are approximately 650, 480 and 1000 ppm for Rb, Ba and Li, respectively. The concentrations of these elements in the retrograde fluid are of an order comparable to that of fluid from subducting AOC or sediment, but they cannot be explained by linear mixing of AOC fluid and sediment fluid.

The result (4) implies that observed variation in trace element and isotope composition could reflect global differentiation common to the subduction zone fluid processes.

These results suggest that identifying mass transfer associated with rehydration process is possible, by focusing samples collected exclusively from the same basic block, whose samples are likely to have suffered the same P-T path and had a similar initial composition before subduction. A comprehensive study combining metamorphic texture, bulk trace and isotopic composition and thermodynamic analysis at Sanbagawa metamorphic belt has a potential to resolve the fluid processes in the subduction zone.

Keywords: metamorphism, fluid, trace element, isotope, Sanbagawa metamorphic belt, Geofluid